3D Augmented Reality Application

PREPARED UNDER

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***Abstract*— The aim of this project is to implement a 3D Augmented Reality application in android operating system. Using 3D is becoming quite common for professionals as well as users. Some of the examples include 3D maps, 3D gaming,3D cinema etc. Implementing a mobile application that takes advantage of 3D as well as Augmented Reality may be very useful for planning new constructions in allowing to visualize how the construction will be in the future and how will it interact with its surrounding environment. 3D modeling and AR also has extensive uses in the field of ergonomics. The project requires extensive knowledge in the Modeling and Animation using softwares such as Blender, Unity, ZBrush and vuforia. 3D modeling also requires skills like creativity of an artist to sculpt or model a character with fine details.**

Keywords—Augmented Reality, Modeling, Rigging, Skinning, Animation, Animator, Rigify, Armature, Unity, Blender, ZBrush, Vuforia, Character Controller

I. INTRODUCTION

Augmented Reality (AR) turns the environment around you into a digital interface by placing virtual objects in the real world, in real-time. AR can be seen through a wide variety of experiences such as gaming applications, AR browsers, etc.

Unity is a cross-platform game engine. It was developed by Unity Technologies. This project will use Unity as an important development platform. With the help of Unity 3D engine, users can develop their own games. They can also create a virtual world for various applications, or remake a real world entity in the virtual one. This project emphasizes on the remaking of real world objects such as 3D remake of a humanoid model.

Vuforia AR SDK is an augmented reality software development kit for mobile devices that enables the creation of augmented reality applications. Vuforia AR SDK provides a framework to create markers that will help identify each marker that this project is going to implement.

Android Studio is the official integrated development environment (IDE) for Google's Android operating system, built on JetBrains' IntelliJ IDEA software and designed specifically for Android development. The Android software development kit (SDK) includes a comprehensive set of development tools. Ease of Use

II. LITERATURE SURVEY

A. Base Papers

All the research papers describe different applications of augmented
Reality.

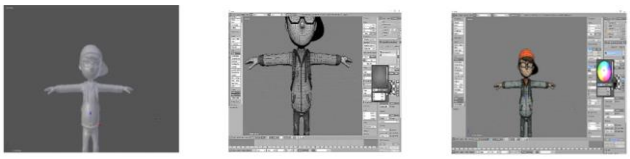
1. In the **first** paper, *Learning to Create 3D Models via an Augmented Reality Smartphone Interface,Jeff K.T. Tang,Tin-Yung Au Duong, Yui-Wang Ng, Hoi-Kit Luk. IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE) DEC 2015 [1]*

a mobile application is built with the help of Augmented Reality (AR) [1] which will assist in building 3D models and help the student to learn these skills and concepts easily. Here via cell smartphone UI, the client assembles a model with primitive blocks in a "bottom up" way like "LEGO" blocks. These squares are pictured on the printed marker cards that permit users to control (pivot, interpret, and so on) them similarly to controlling genuine structure blocks.

2. In the **second** paper, *3D animation model with augmented reality for natural science learning in elementary school,F Hendajani , A Hakim , M D Lusita , G E Saputra and A P Ramadhana, 4th International Seminar of Mathematics, Science and Computer Science Education 2018 [2]*

Natural Science learning media uses 3-dimensional animation models (3D) with augmented reality technology[2], which offers some visualization of science lessons. This application was created to visualize a process in Natural Science subject matter. The hope of making this application is to improve student's concepts. This app is made to run on a personal computer that comes with a webcam with augmented reality. The app will display a 3D animation if the camera can recognize the marker. Here it is done in three steps-:

1. ***3D model animation with 3D Blender-:***



(a) Making the skeletons of the human body (b) Texturing 3D Object, (c) 3D Object Coloring Technique with RGB Color.

2. ***Use of Vuforia-:***

The next step is to set up the marker used. Here Vuforia's help
Is taken to display a 3D object in front of the camera.

3. ***Making marker with Unity-:***

This software is used to be able to read the marker with the help of the AR Camera inside Unity.

(a) (b) (c)

Figure 8. (a) 3D Object to Image Target, (b) Positioning the Target Image 3D Object, (c) Add Description.

3. The **third** *paper Physical Rigging Procedures Based on Character Type and Design in 3D Animation. International Journal of Recent Technology and Engineering · OCTOBER 2019 [3]* explores the fundamental process of character rigging system and identifies the method and techniques for rigging characters based on their anatomy designs. The analysis of this study also looks at the conceptual design of the character; how to implement proper techniques and workflow based on the primary and secondary data provided in the study.

Abstract: In 3D (Three-Dimensional) animation pipeline, the term rigging is commonly used to describe the process of creating a skeleton system inside the finishing 3D character geometry and assigning animation controllers for animators to animate the 3D character. In order to establish a fluidity movement on the character, the proper setting must be planned and the flexibility of the controller must be set up properly.

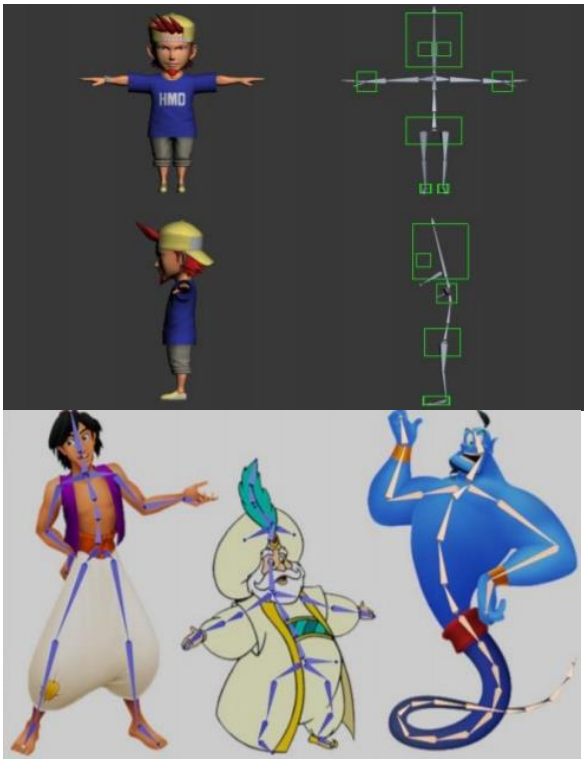
Conclusions: There are several ways to develop system rigging for human characters, such as using bone objects, CAT, or biped. Biped and CAT are rigging options that are available in 3D software such as 3ds Max.

The suitability of rigging type depends on the purpose of the character and how the character will be presented.

From observation, the authors found that most of the common techniques for human rig objects in 3D characters are using Biped, CAT or **auto rigs**.

Auto rig is easy to set up and the process does not take much time. However, for cartoonish human characters, the setup is a bit tricky and difficult because it is heavily depending on custom bone setup.

From the experiments, the authors found that biped or CAT rigging is the best setting for the realism characters and custom rig for cartoonish characters.



B. Other Research Papers

1. Paper: - **3D GAME DEVELOPMENT USING UNITY GAME ENGINE**

This paper present the design and implementation of the game called Cognitive Arenas.
It is a very common game and was developed keeping the Mac OS X and Windows Operating Systems in mind. The aim behind the project was to promote education via innovation. The students playing this game can learn their given material in one of the paper modules and answer the questions asked in the game where simultaneously he play the shooter game.
The player can move to three levels of scenes depicted in Unity3D Game Engine and 3ds Max to play the game interestingly.

2. Paper: - **Using Unity 3D to Facilitate Mobile Augmented Reality Game Development**

This paper [5] applied mobile AR to develop the Calorie Battle AR exergame to tackle worldwide childhood obesity. In this game the player finds and defuses virtual calorie bombs in a real world environment. This paper presents the development of two game versions.
First prototype was created without a third party game engine and it led to many challenges.
To explore solutions to these challenges, they created a new version of the game with the Unity 3D game engine. Using Unity 3D, the game development process was simplified.

A mixed-method usability evaluation on children and university students indicated that especially interaction with AR content and user interface clarity were improved in the Unity3D version. This study produced three important contributions:
1) a novel mobile AR exergame to motivate children to move;
2) reimplementation of the game using the Unity 3D; and
3) results of a usability evaluation comparing two game versions.

3. Paper: - **A Survey of Augmented Reality, Ronald T. Azuma Hughes Research Laboratories**

This paper[6] surveys the field of Augmented Reality, in which 3-D virtual objects are integrated into a 3-D real environment in real time.
It describes the medical, manufacturing, visualization, path planning, entertainment and military applications that have been explored.
This paper describes the characteristics of Augmented Reality systems, including a detailed discussion of the tradeoffs between optical and video blending approaches. Registration and sensing errors are two of the biggest problems in building effective Augmented Reality systems, so this paper summarizes current efforts to overcome these problems. Future directions and areas requiring further research are discussed. This survey provides a starting point for anyone interested in researching or using Augmented Reality.

4. Paper: - **Recent Advances in Augmented Reality**

The goal of the survey [7] is to cover the recent advances in Augmented Reality.
Calibration and Auto calibration - AR systems generally require extensive calibration to produce accurate registration. Measurements may include camera parameters, field of view, sensor offsets, object locations, distortions, etc.
Interfaces and Visualization - In the last five years, AR research has become broader in scope. Besides work on the basic enabling technologies, researchers are considering problems of how users will interact and control AR applications, and how AR displays should present information.
User Interface and Interaction - Until recently, most AR interfaces were based on the desktop metaphor or used designs from Virtual Environments research. One main trend in interaction research specifically for AR systems is the use of heterogeneous designs and tangible interfaces.
Visualization Problems - Researchers have begun to address problems in displaying information in AR displays, caused by the nature of AR technology or displays. Work has been done in visualizing the registration errors and avoiding hiding critical data due to density problems

5. Paper: - **CURRENT TRENDS IN AUGMENTED REALITY AND FORECASTS ABOUT THE FUTURE**

In this study [8], "in-depth literature review" method is used. "In-depth literature review" is used to examine the literature more intensely, deeper, with more sizes and more components in a wider scope, to perform a healthier analysis, to make more accurate assessments and to understand the current situation better. Current reports and trends are analyzed in depth and future predictions are included.
In the study titled “Hype Cycle for Emerging Technologies” conducted by Gartner Inc. in 2015, in its fifth level theme called “Digital Business” the focus is on convergence of people, businesses and objects and connection between them. AR ranks at the fifth level and is shown among the trends that are thought will reach widespread usage in 5-10 years.
In its report titled “Mobile AR: Smartphones, Tablets and Smart Glasses 2013-2018” Juniper Research, one of the technology research companies, mentions that annual revenues in sectors in the AR services and applications have reached $1.2 billion. The number of single users of AR applications has risen to 60 million in recent years and this figure is expected to reach to 200 million by 2018.
In a report of Goldman Sachs in 2016, about the use of AR in education, the worth of educational software produced with AR is expected to be $300mn in 2020 and to rise to $700mn in 2025.

6. Paper: - **The Impact of an Augmented Reality Application on Learning Motivation of Students**

The purpose of this research [9] was to measure and understand the impact of an augmented reality mobile application on the learning motivation of undergraduate health science students at the University of Cape Town. The intrinsic motivation theory was used to explain motivation in the context of learning. The attention, relevance, confidence, and satisfaction (ARCS) model guided the understanding of the impact of augmented reality on student motivation, and the Instructional Materials Motivation Survey was used to design the research instrument. The research examined the differences in student learning motivation before and after using the augmented reality mobile application.
A total of 78 participants used the augmented reality mobile application and completed the preusage and postusage questionnaires. The results showed that using an augmented reality mobile application increased the learning motivation of students. The attention, satisfaction, and confidence factors of motivation were increased, and these results were found to be significant. Although the relevance factor showed a decrease it proved to be insignificant.

7. Paper: - **Motion in Augmented Reality Games: An Engine for Creating Plausible Physical Interactions in Augmented Reality Games**

The paper[10] describes the design and implementation of the MARG(Motion in Augmented Reality Games) engine and presents two proof-of-concept AR games that have been developed using it. Evaluations of these games have been performed and are presented to show that the MARG engine takes an important step in developing the next generation of motion-rich AR games.
In order for the next generation of AR games to create the illusion that they are set in environments in which real and virtual objects coexist, these objects will need to exhibit plausible physical interactions. These interactions will need to take place in three dimensions, cannot be limited to a

small number of special objects, and the level of sophistication of interactions between real and virtual objects must be high. The second requirement is that physical interactions between real and virtual objects not be limited to a small number of special objects. The third requirement is that the apparent physical interactions between real and virtual objects be simulated in a plausible and sophisticated way.

III. Methodology

A. *Tools required for Implementation*

1. Unity
2. Vuforia
3. Android Studio (SDK)
4. Java Development Kit (JDK)
5. Blender
6. ZBrush

B. *Proposed Idea*

The **first** phase of the problem is modeling a humanoid 3D model using Unity. After which animations will be added to the character using Unity animator tools and techniques.

Using Vuforia, the image target object will be set and stored in the database for creating an AR target object.

The **second** phase begins with adding animations to the model which involves stages like rigging and skinning of the character. The Unity project will be integrated and exported as an Android application using Android Studio SDK toolkit. The app requires a JDK environment for set-up and running. Other features like multiple character modeling and touch features may also be added.

The **third** phase involves adding additional functionalities for the app such as User Interface, Multiple animations and transitions, third person character Controller in AR and touch features.

IV. Implementation

The implementation is done in 4 stages basically and each stage will be discussed in detail:

1. AR Image Target settings
2. Modeling
    - **a.** Sculpting and Texturing
    - **b.** Rigging
    - **c.** Skinning
3. Animation
4. App development
    - **a.** Animator Blend Tree for animation Transitions
    - **b.** UI design
    - **c.** Buttons
    - **d.** Joystick
    - **e.** Character Controller
    - **f.** Lean Touch: Pinch to Scale

A. *AR Image Target settings*

Steps for implementing:

1. First we need to create a Vuforia developer account.
2. The target photo was taken and cropped which will serve as ground for the humanoid model for further animation.
3. I created a database in vuforia of type device.
4. The image was uploaded in Vuforia's database and the AR model of image was generated with an augmentable rating of 5 stars.
5. The database was then downloaded and imported inside the Unity project and dimensions were adjusted accordingly.

g. **Notebook cover photo taken from camera**

h. AR Model of the notebook created by Vuforia Database and imported in Unity

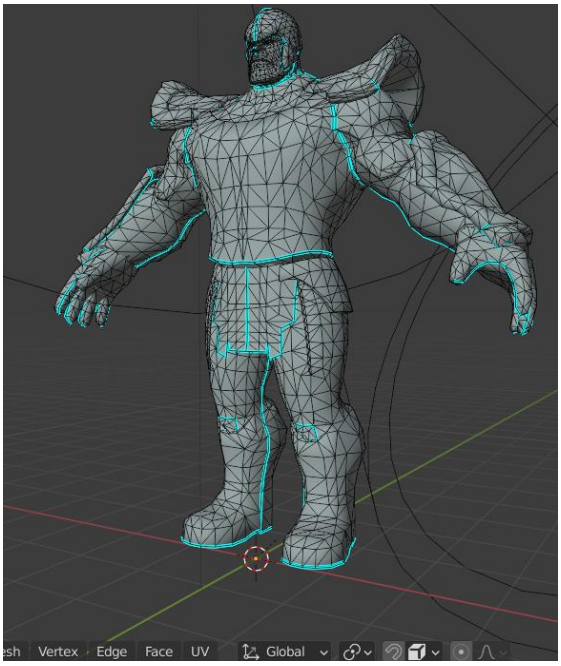
B. Modeling

Modeling of the character was done using Blender and ZBrush.

We have taken Fig.(c) as the reference for the character Model "**Thanos".**

i. Reference Image

j. Polygon based model using Blender



k. Polygon mesh in Blender (edit mode)

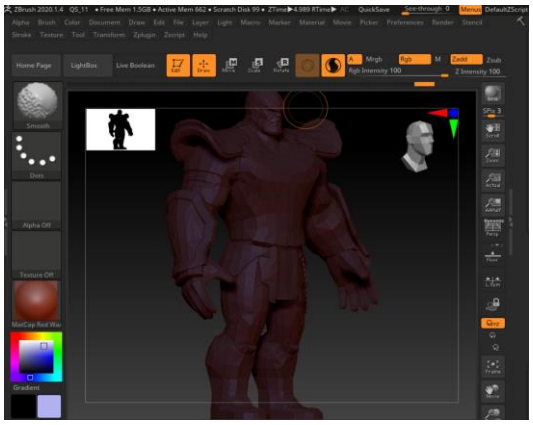
l. Object mode in Blender

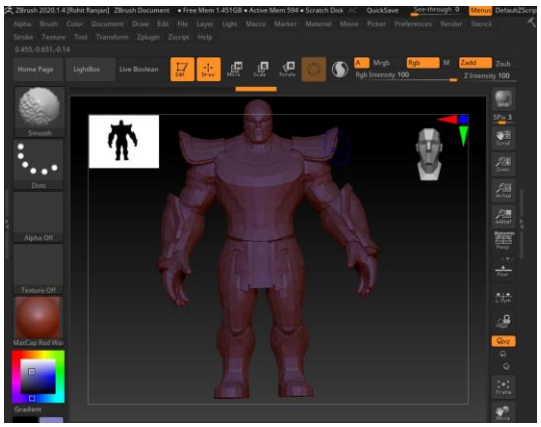
ZBrush has a variety of sculpting brushes such as:

- Smooth brushes
- Clip brushes
- Curve brushes which make use of the Stroke Curve mode
- Planar, Trim and Polish brushes – ideal for hard surface sculpting
- Groom brushes – designed specially for use with FiberMesh
- Pen brushes – used for QuickSketch

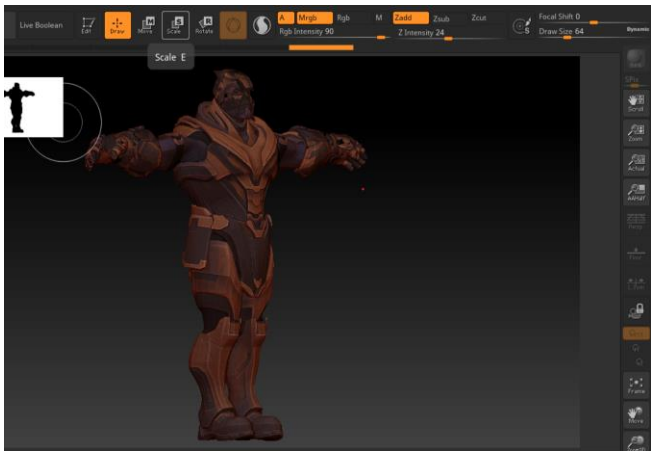
- InsertMesh brushes – quick access to any mesh you can imagine
- Curve Bridge brush – create polygon bridges to weld edges
- ZSketch brushes – special brushes only used for ZSketch
- Alpha 3D brushes – full 3D alpha brushes with under-cuts

With the help of these tools the model mesh was fine tuned in ZBrush to obtain the desired results as shown below:





a. Zbrush sculpting and texturing



b. Final model after sculpting in ZBrush

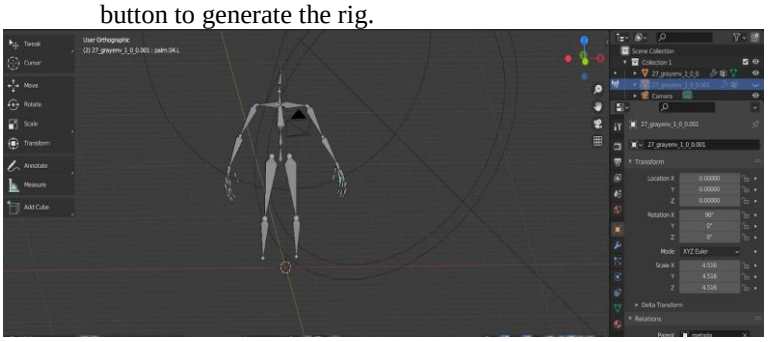
C. Rigging

Blender comes with a free add-on called **Rigify** that provides models with a biped rig. Rigify helps automate the creation of character rigs. [11]

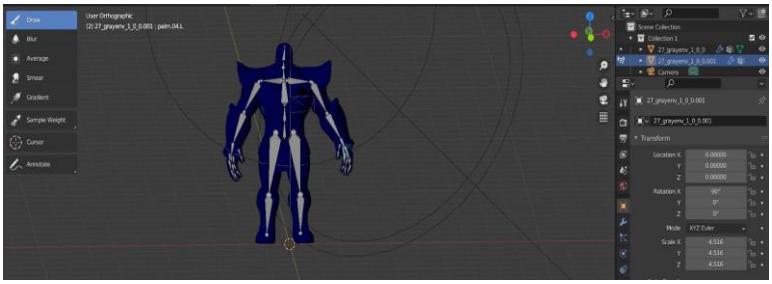
Rigify generates a full rig for the model by using the armature as a template.

Basic Rigging procedure in Blender:

1. Add a meta-rig structure from the Add ‣ Armature menu.
2. Edit the bone positions to match the character geometry.
3. In the armature properties click on the Generate button to generate the rig.

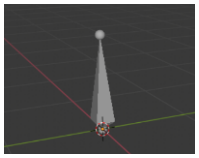


a. Basic Rig created for the character model



b. Model Rig applied on mesh

Armature: An armature in Blender can be thought of as similar to the armature of a real skeleton, and just like a real skeleton an armature can consist of many bones. These bones can be moved around and anything that they are attached to or associated with will move and deform in a similar way. [12]

An armature object has: 

- An origin, a position, a rotation and a scale factor.

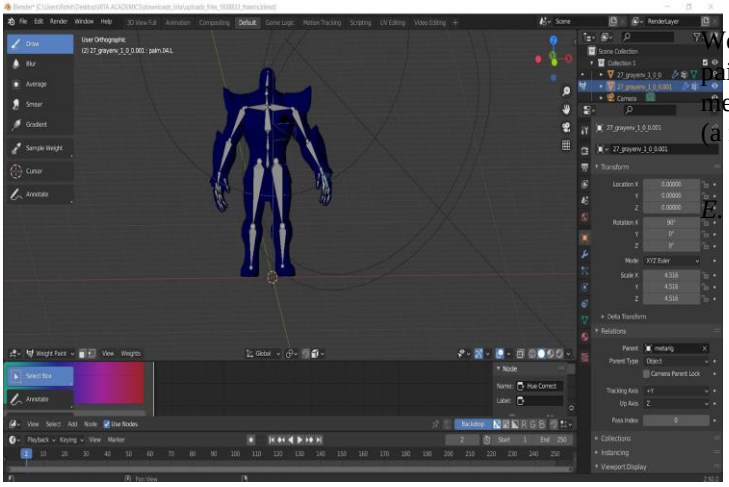
- All animation we do in Object Mode is only working on the whole object, not the armature's bones (we use the Pose Mode to do this).
- Armatures are designed to be posed, either for a static or animated scene, they have a specific state, called "rest position". This is the armature's default "shape", the default position/rotation/scale of its bones, as set in Edit Mode.
- In Edit Mode, we see the armature in rest position, whereas in Object Mode and Pose Mode, we usually get the current "pose" of the armature. [15]

D. Skinning

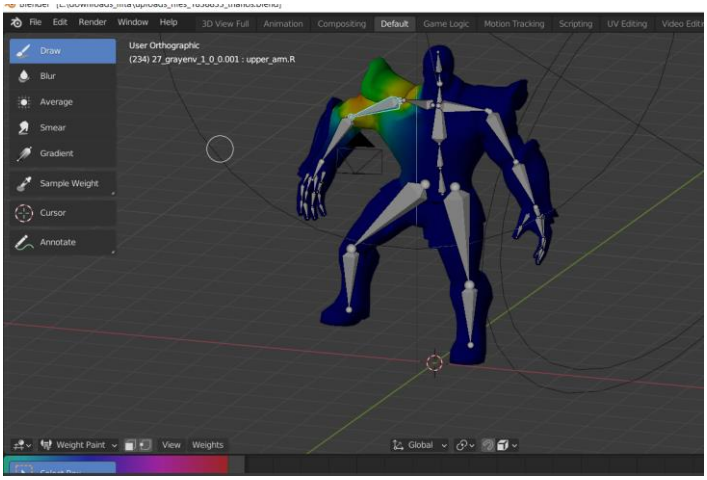
Skinning binds the 3D mesh with the bones (rigging) so that we can move vertices and use the model to the fullest capacity in animation. This is the process of attaching the mesh to the skeleton. [13]
In Blender, we have two main skinning types:

1. We can Parent/Constrain Objects to Bones – then, when we transform the bones in Pose Mode, their "children" objects are also transformed, exactly as with a standard parent/children relationship… The "children" are never deformed when using this method.
2. We can Use the Armature Modifier on the entire Mesh, and then, some parts of this object to some bones inside this armature. This is the more complex and powerful method, and the only way to really deform the geometry of the object, i.e. to modify its vertices/control points relative positions. [16]

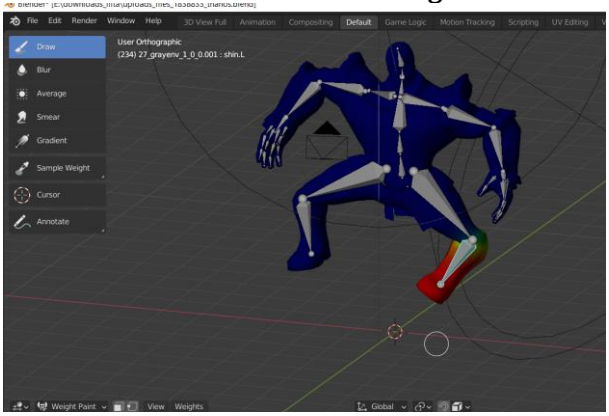
Essentially skinning is the relationship between the vertices in a mesh and the bones of an armature, and how the transformations of each bone will affect the position of the mesh vertices. Once the Armature - the 'character skeleton' - is ready it is necessary to parent the character 'skin' to it. For this we can use **Weight Painting** as shown below:[14]



a. Default mode weight: Blue



b. Shoulder bone weight: Green



c. **Leg bone weight: Red**

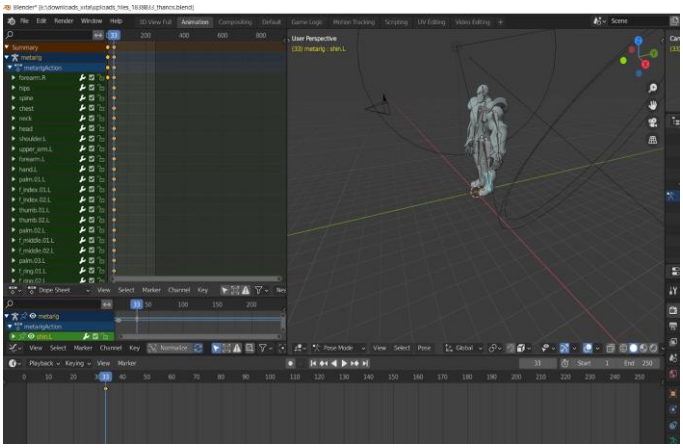
We can enter **Weight Paint Mode** from the Mode Selector Ctrl-Tab. The selected mesh object is displayed slightly shaded with a rainbow color spectrum. The color visualizes the weights associated with each vertex in the active vertex group. **By default, blue means unweighted and red means fully weighted.**

We can assign weights to the vertices of the object by painting on it with weight brushes. Starting to paint on a mesh automatically adds weights to the active vertex group (a new vertex group is created if needed). [14]

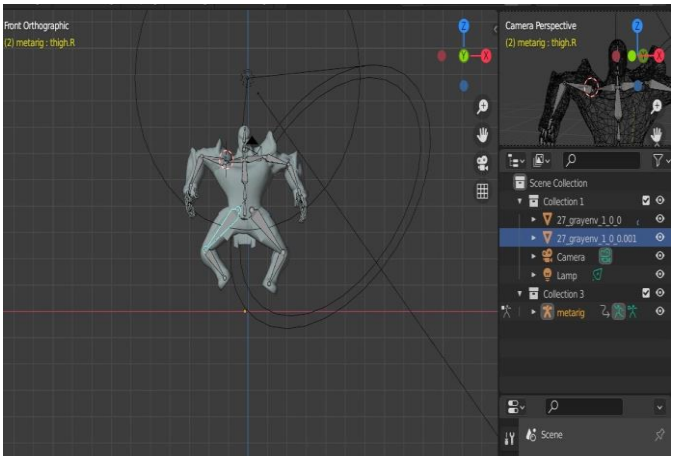
E. Animation

Animation process consists of these steps:

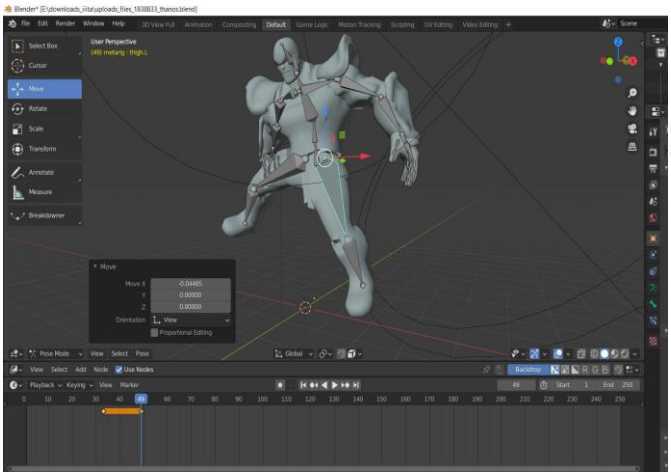
1. In blender, the model is animated in **pose mode**.
2. We start the animation process by inserting an initial keyframe at the starting pose of the character.
3. Then after moving and adjusting the specific bones along with mesh to the desired position (with location and rotation), we insert the next keyframe.
4. After creating a motion clip we can adjust the other setting such as time controls.



a. **All bones generated in armature**



b. Inserting Animation Keyframe at jump position

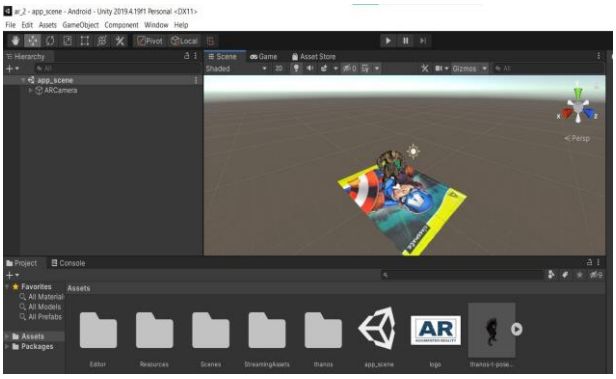


c. Finalizing Keyframe for animation clip

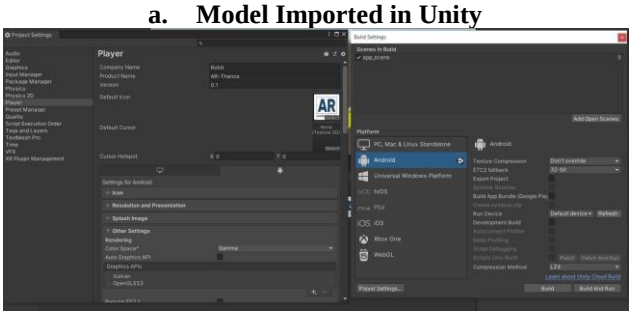
F. App development

Steps for implementing:

1. The character model was imported into the Unity Project and placed on top of the image target.
2. Animation clips were imported into the unity project and applied to the model using the **Animator** tool in Unity.
3. Textures and Materials were created for the model as “New materials” for the model and their albedo was set.
4. JDK and Android SDK libraries path were added to the project.
5. Build settings were set and the scene was added to be exported as an Android app.



a. Model Imported in Unity



b. Build setting and player setting

G. Additional Features added: Phase 3

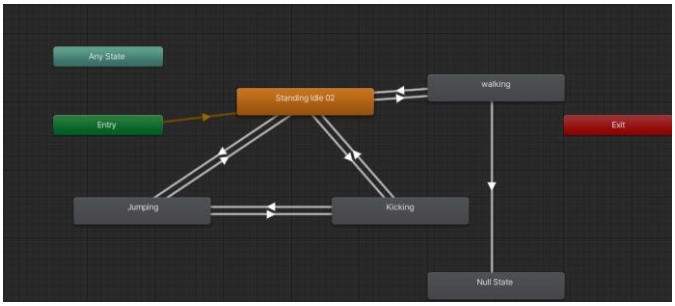
In the phase 3, some additional features were added to convert a simple animation app into an 3D character game in Augmented Reality space with features to move the character using Joystick and perform jump and attack motions along with respective animations. A User Interface was constructed with Buttons and Joystick and Lean Touch was added as a feature. Then the app was rebuilt.
Features added in phase 3:

- Multiple Animations
- User Interface: Buttons and Joystick control
- Character Controller
- Touch Features: Pinch to scale

*1) **Multiple Animations**:*

Animator Controllers are state machines that determine which animations are currently being played and blends between animations seamlessly. An Animator Controller allows you to arrange and maintain a set of Animation Clips and associated Animation Transitions for a character or object. [17]
The Animator Controller has references to the Animation clips used within it, and manages the various Animation

Clips and the Transitions between them. To set up these conditions, we specify values of parameters in the Animator Controller.



2) User Interface: Buttons and Joystick

UI canvas was created with buttons for transitioning between animations (Idle, Jump, Attack and walk). Gradient button icons were created in Photoshop.

A script for Joystick was written for the character controller to move and rotate the character in 3D Augmented reality world space.

3) Character Controller

A Character Controller allows one to easily do movement constrained by collisions without having to deal with a rigidbody. [18]

A Character Controller is not affected by forces and will only move when we call the Move function. It will then carry out the movement but be constrained by collisions.

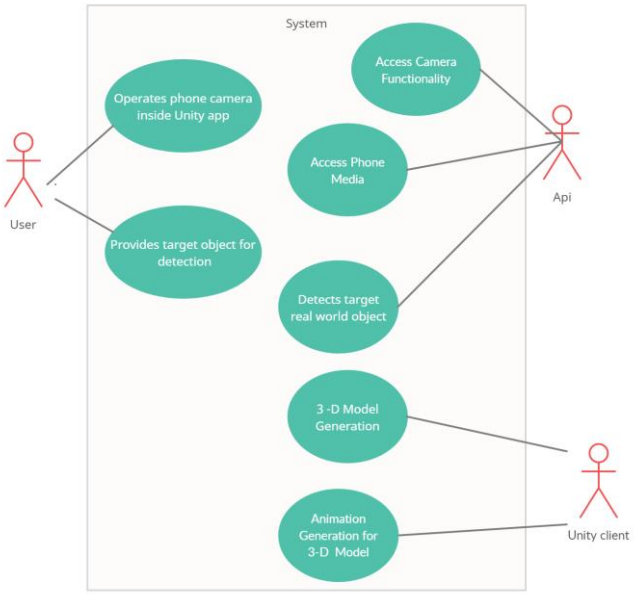
A third person character controller script for AR world space with features to move, rotate, jump and attack along with animations was created. Joystick was added as input for the character Controller.

4) Touch: Pinch to scale

Pinch to scale feature was added using Lean Touch in Unity to scale up and scale down the character using fingers pinch. This event gets called every time a finger begins touching the screen, and gets passed a Lean.

Lean Touch was imported from Unity Asset store and added to the character model as component.

V. USE CASE DIAGRAM



VI. EXTERNAL INTERFACE REQUIREMENTS

A. User Interface

The user will interact with the AR application via phone camera. The Unity application will access the phone camera and perform its functionalities.

B. Hardware Interface

The app requires an extensive use of the device's camera. It will also use the device's screen capture utility. Also, the user will use the device's "back", and "home" buttons. All these functionalities will be implemented using Android SDK after creating the Unity application.

VII. NON FUNCTIONAL REQUIREMENTS

A. Performance Requirements

Our software application must detect target objects which are stored in the Vuforia database with ease and efficiency for smooth user experience and animation should be generated without any glitch or delay.

B. Business requirements

This code will be open source, and it can be used by anyone as their own choice.

C. Performance attributes of software

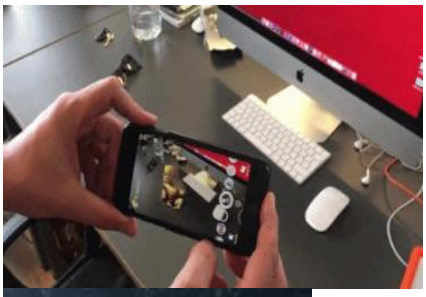
The software offers simple and advanced functionality to the user. We are focused on creating a very user-friendly android application that is easy to use and easy to understand. The software is highly compatible and can be even converted into a desktop or iOS application with slight modifications in the development phase.

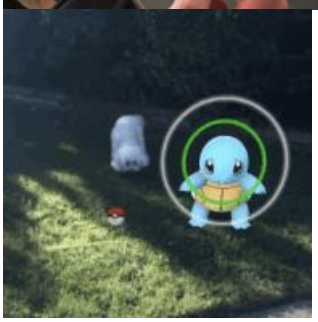
VIII. Results and Discussion

The character "**Thanos**" was modelled beautifully using the modeling softwares and the animation generated after the rigging and skinning process in the application is quite smooth. The image target tracking for the marker based AR app is of extremely high accuracy. AVI/demo of the app has been included in the project folder. The results are shown below:

IX. Comparision with existing projects

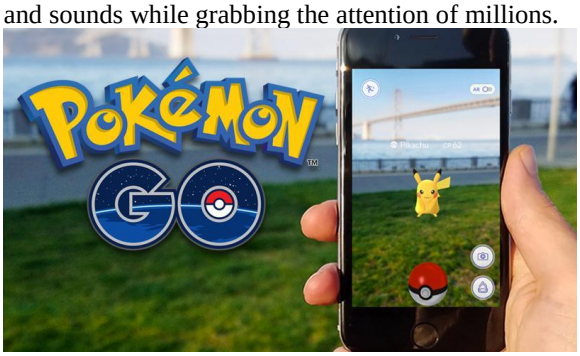
Some of the existing AR application are shown below. Most of them are based on same principles and use the similar techniques and methods in their implantation. But the features depend upon the developer. These features can be added or extended as per requirement of the user with proper time investment and experience of modeling softwares.





X. Appications of the project and scope

1) ***AR is the future of Game Industry*** : Pokemon Go is one of the most loved games of augmented reality. Due to its reputation and marvelous gaming experience it has won the heart of millions. It is favoured with a vision-based algorithm that gives exceptional clarity to object, graphics, and sounds while grabbing the attention of millions.



Our project is very similar to this game as it provides interaction with 3D humanoid models in AR world with character controller.

2) ***AR in medicine/Education*** : Complete Anatomy is arguably one of the most powerful AR apps in anatomy education. It delivers virtual models of the human body based on classic textbooks and anatomical papers.

3D4Medical by Elsevier [19] is an award-winning 3D technology company that specializes in medical, educational and health & fitness software for student/patient education. Students can explore the body down to the cellular level. Furthermore, you can select specific organs and see them at work. For example, you can view the heart in action. You will see how blood circulates with the real-time beating of the heart.

Our project can serve as basis for similar tech if we change the character model to a human body anatomy model with required additional functionalities.

3) ***AR in Entertainment Industry*** : AR is fast disrupting industries across the board, from retail to healthcare, bringing new and exciting opportunities for brand engagement and word of mouth sharing.

The entertainment industry – including film, theatre and museums – are particularly well suited to the benefits of AR, whether the goal is to improve brand recognition or sell more tickets.

The reason why AR is so powerful when it comes to Entertainment is because it allows brands to transport users to the worlds and characters they have created, both delighting them and encouraging them to share it on social.

XI. Conclusion and Future scope

A 3D Augmented Reality Application was developed after extensive training and learning of animation and modeling softwares such as Unity, Blender, ZBrush and Vuforia. The application was developed after an extensive literature survey analysis of 10 research papers in the field of AR. Modeling and animation techniques such as Rigging, Skinning, Sculpting, texturing as well as android application building techniques were involved in the implementation and learning process.

The project has an immense future scope in the field of AR Game development and also in the field of animation and films. The character model can be used in many PC/video game and android/iOS games.

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